THERMAL RADIATION FROM MISSILE PLUMES AND SHOCKS

Electro-Dynamics Laboratory
ENGINEERING EXPERIMENT STATION
UTAH STATE UNIVERSITY
Logan, Utah

Monthly Progress Report No. 13
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GEOPHYSICS RESEARCH DIRECTORATE
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OFFICE OF AEROSPACE RESEARCH
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Prepared for

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ABSTRACT

This constitutes Monthly Progress Report No. 13, covering the period from 15 September 1961 to 15 October 1961 under Air Force Cambridge Research Laboratories Contract No. AF19(604)-7423 to Utah State University. The objective of the research is the development and employment of instrumentation for the measurement of the spectral radiation characteristics of the exhaust plumes and atmospheric shockwaves of high-altitude rockets. Thermal measurements systems to obtain spatially resolved plume radiance data as a function of wavelength and altitude from rocket-borne instrumentation pods are being fabricated, tested and installed.

The prototype system has been completed and was employed in a static firing test at the missile agency. A second system has been installed in a rocket "piggy-back" pod at the missile agency. A third system is complete and will be used as a stand-by system for the initial launch. A checkout console has been developed for the field operation of the system.

The development and fabrication status of the subsequent systems is given, project personnel are listed, administrative action is outlined, and purchases are reported. An estimate of the contract fiscal balance of 1 October 1961 is made.

INVESTIGATIONS BEING UNDERTAKEN AND PLANNED

OBJECTIVES

The objective of this research is the investigation of the spectral radiation characteristics of high-altitude rocket exhaust plumes and atmospheric shockwaves. Instrumentation will be optimized, and radiance measurements obtained in a series of rocket-borne experiments.

Accordingly, the research, coordination and planning was accomplished for the design, development, and fabrication of a prototype instrumentation system.[1] A rocket exhaust spectrum analyzer is being designed which will be capable of measuring the rocket exhaust plume as a function of position or longitudinal axis, spectral wavelength, and time.

Additional telemetry systems are being fabricated and tested for installation in rocket aircraft or satellite instrumentation pods. Improvements and modifications are being incorporated in the second generation systems. Equipment installation and pre-flight checkout will be accomplished prior to the launch of each system. Reduction and analysis of the data obtained from these flights will be performed.

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[1] L. S. Cole and D. J. Baker, "Thermal Radiation from Missile Plumes and Shocks," MPR No. 6 AFRD Contract No. AF19(604)-7423, Utah State University, Logan, Utah, p. 3: March 15, 1961.

An attempt is being made to devise the most feasible approach to the missile plume radiation measurement program. This will insure that all data acquired is applicable to existing requirements. Feasibility studies of the use of an interferometer for background studies during midcourse are being performed, and the use of AFCRL thermal detectors in experiments during all stages of the rocket trajectory is being investigated.

TECHNICAL PROGRESS

USU Thermal System No. EDL-4 was delivered to the Atlantic Missile Range, Florida, and installed in Atlas Piggy-Back Pod No. 3 on USU-SV Thermal Plume Measurements Experiment No. 6. This [illegible] by Messrs. C. L. Wyatt and L. R. Taylor of USU [illegible] 1966.

[illegible] incorporated several design improvements over the previous system to provide more dependable operation under conditions of low pressure, vibration, and long pre-flight operation.

The electronic circuitry of Experiment No. 6 as it is installed is given on the [illegible] preamplifier assembly is shown in Figure [illegible]. Microphonic effects are eliminated by floating the negative [illegible] volt d-c supply and grounding the +15 volt point.

The preamplifier circuit is shown in Figure 2. A 150-ohm [illegible] was added in series with the output to protect the 2N338 output stage from overload due to output shorts.

The air-UV and B-UV dispersion unit spectrometers utilize [illegible] linear preamplifiers to extend their dynamic range for a greater variation of inputs. The curves of preamplifier voltage output as a function of current input are given in Figures 3 through [illegible]. Preamplifier 6, Figure 3, is used with SLU-16; preamplifier 7, Figure 4, is used with SUV-10; preamplifier SP 6 and SP 7 are spares.

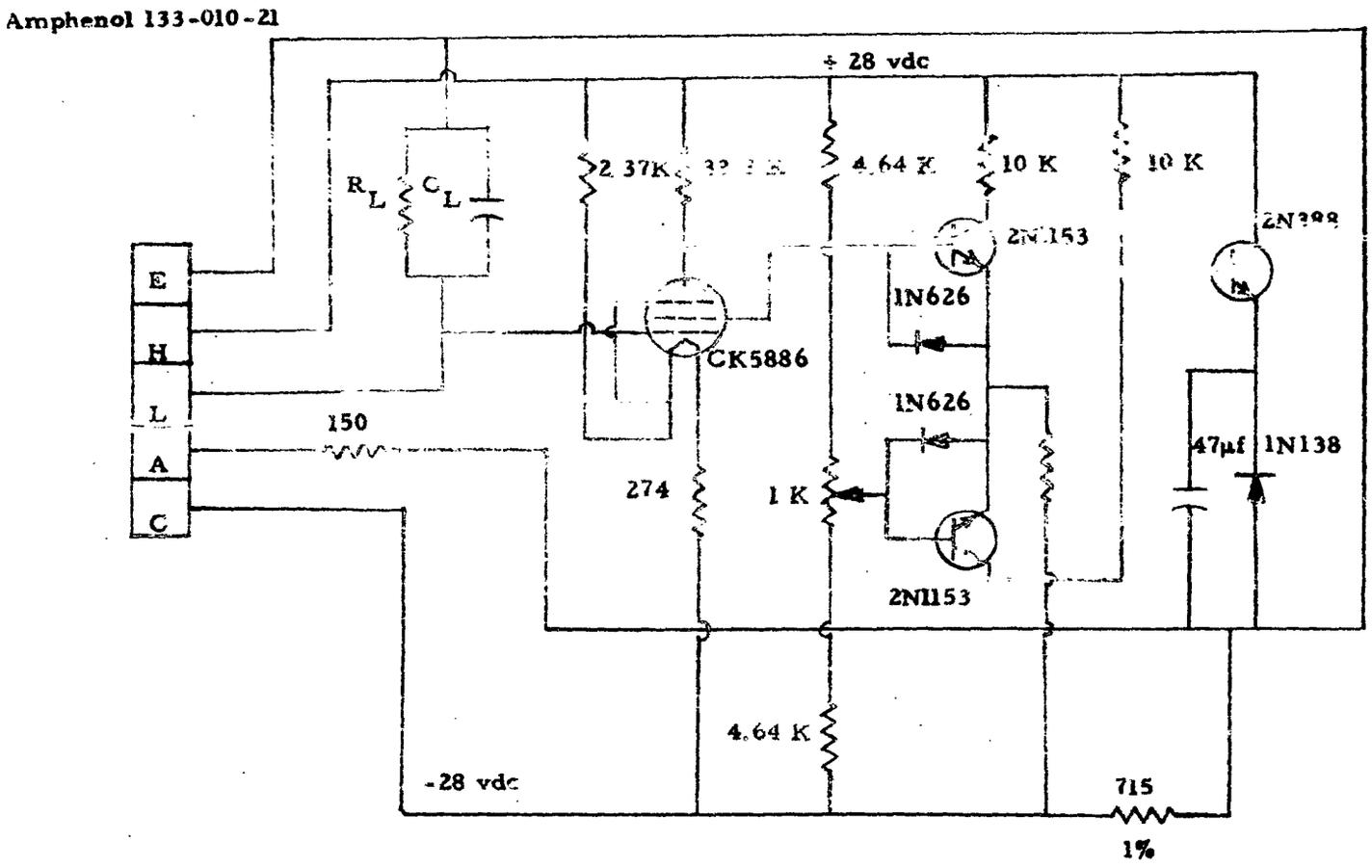

Figure 2. The USU preamplifier plug-in sub-chassis.

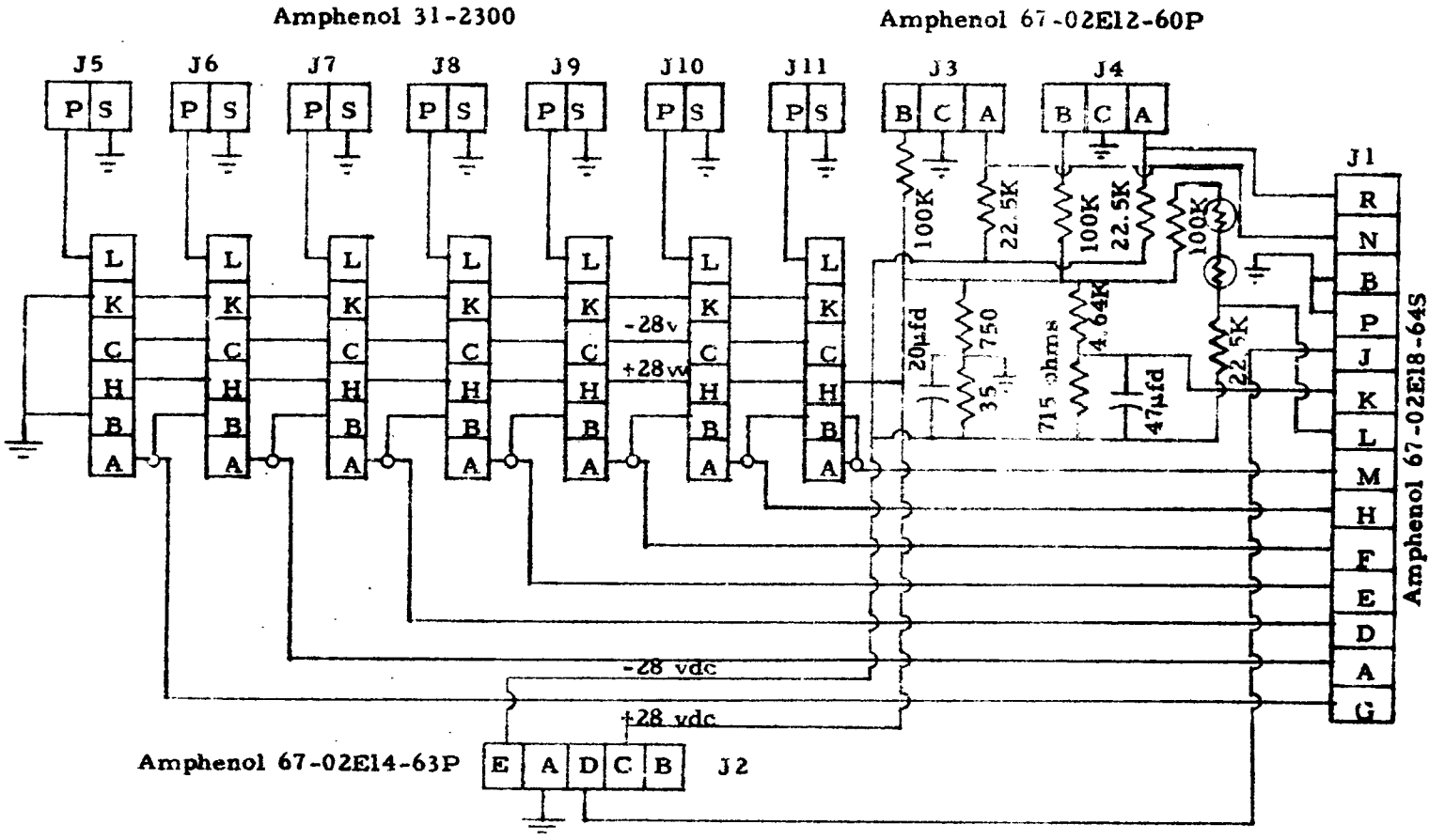

Figure 1. Preamp box.

Table 1. USU UV experiment No. 6 in Piggy-Back Pod No. 3.

USU Sensor	GD No.	GD Desig.	Preamplifier No.	In	Element	Out	Noise (p to p)	Channel No.	Segment		
LV	PB-3-6-1	LV-1	-	J2	-	K	-	14	1,	31	(2.5 rps)
HV	PB-3-6-2	HV-1	-	J2	-	K	-	14	3,	33	
Temp-F	PB-3-6-3	Temp-1	-	J3	-	N	-	14	5,	35	
Temp-A	PB-3-6-4	Temp-2	-	J4	-	R	-	14	7,	37	
Temp-P	PB-3-6-5	Ref 2	-	-	-	L	-	14	9,	39	
OZO-8F	PB-3-6-6	OZO-1	5	J9	IR CMDE 50M	F	.24	15	9		(5 rps)
NUV-13A	PB-3-6-9	BLU-1	7	J11	IR C DCF 50M+D	M	.06	15	15		
NUV-17F	PB-3-6-7	OZO-2	2	J6	IR C DCF 50M	A	.04	15	11		
FUV-5A	PB-3-6-10	Ref-1	3	J7	Dal DCF-2 50M	D	.26	15	17		
BLU-16A	PB-3-6-8	NUV-1	6	J10	IR C MDF 50M + D	H	.04	15	13		
FUV-25F	PB-3-6-11	FUV-1	4	J8	Dal DCF-2 50M	E	.32	15	19		
OZO- A	PB-3-6-12	FUV-2	1	J5	IR C DCF 50M	C	.28	15	21		
0% Cal	PB-3-0-4	0% Cal						15	25		
50% Cal	PB-3-0-5	50% Cal						15	27		
100% Cal	PB3-0-6	100% Cal						15	29		

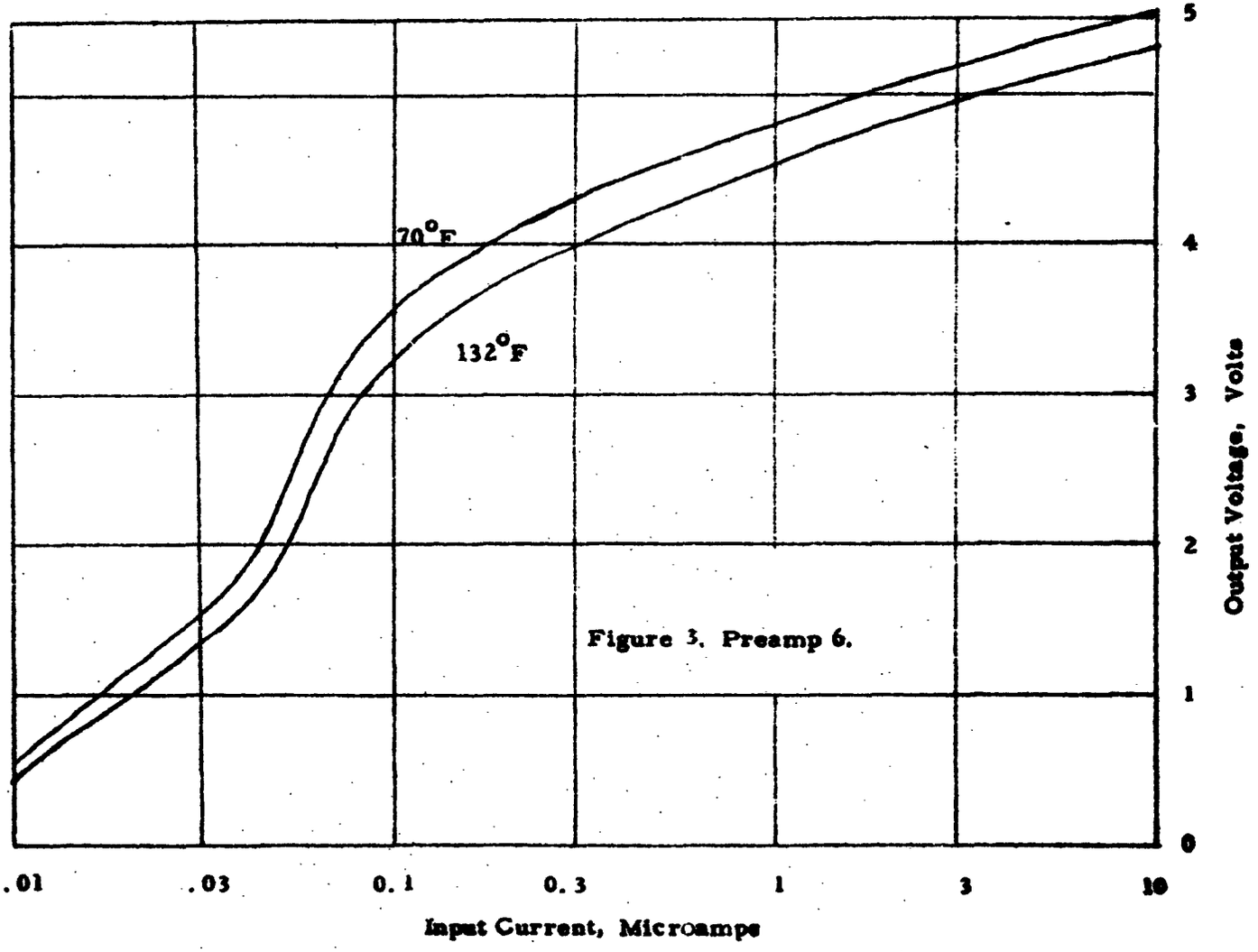

Figure 3. Preamp 6.

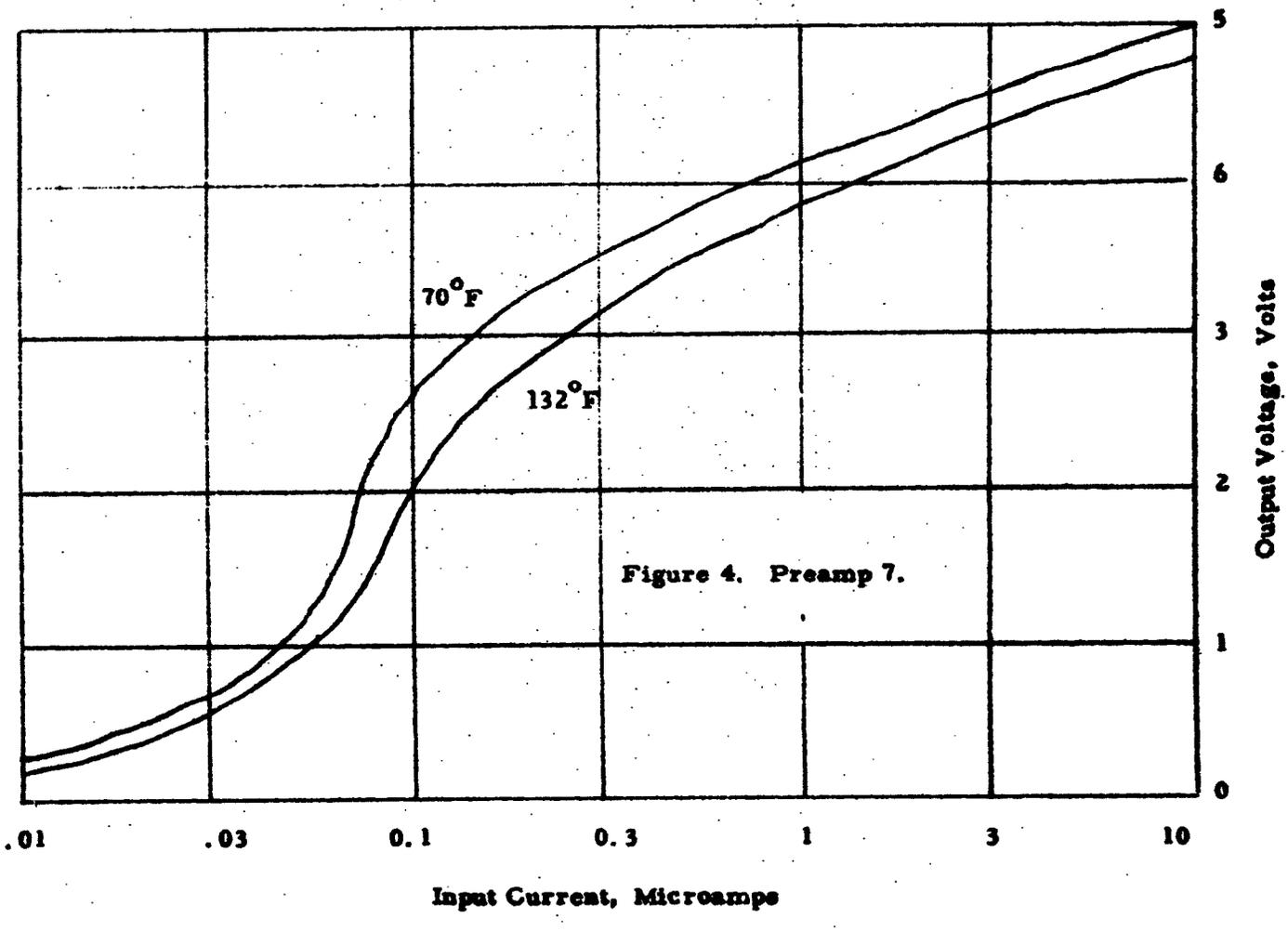

Figure 4. Preamp 7.

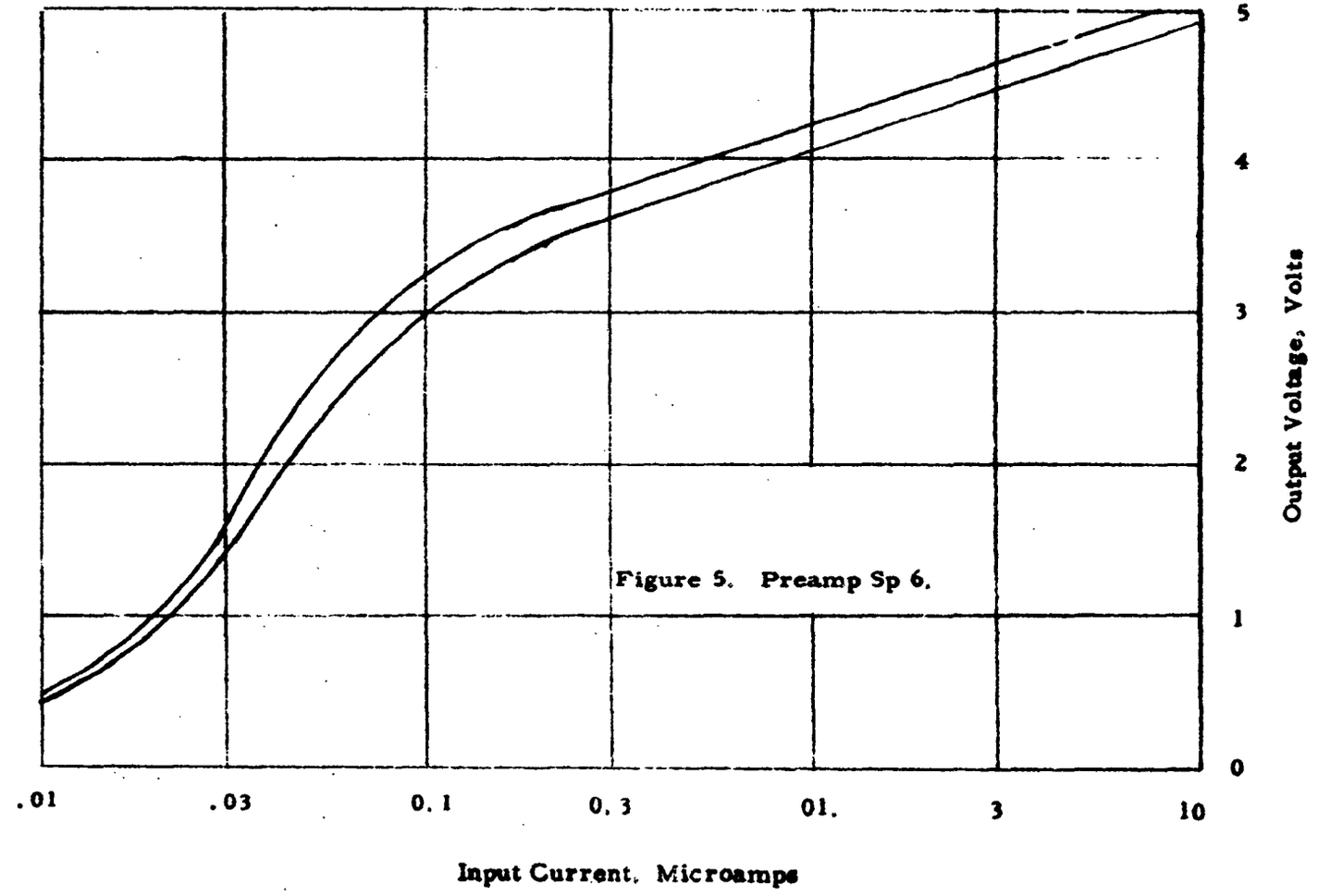

Figure 5. Preamp Sp 6.

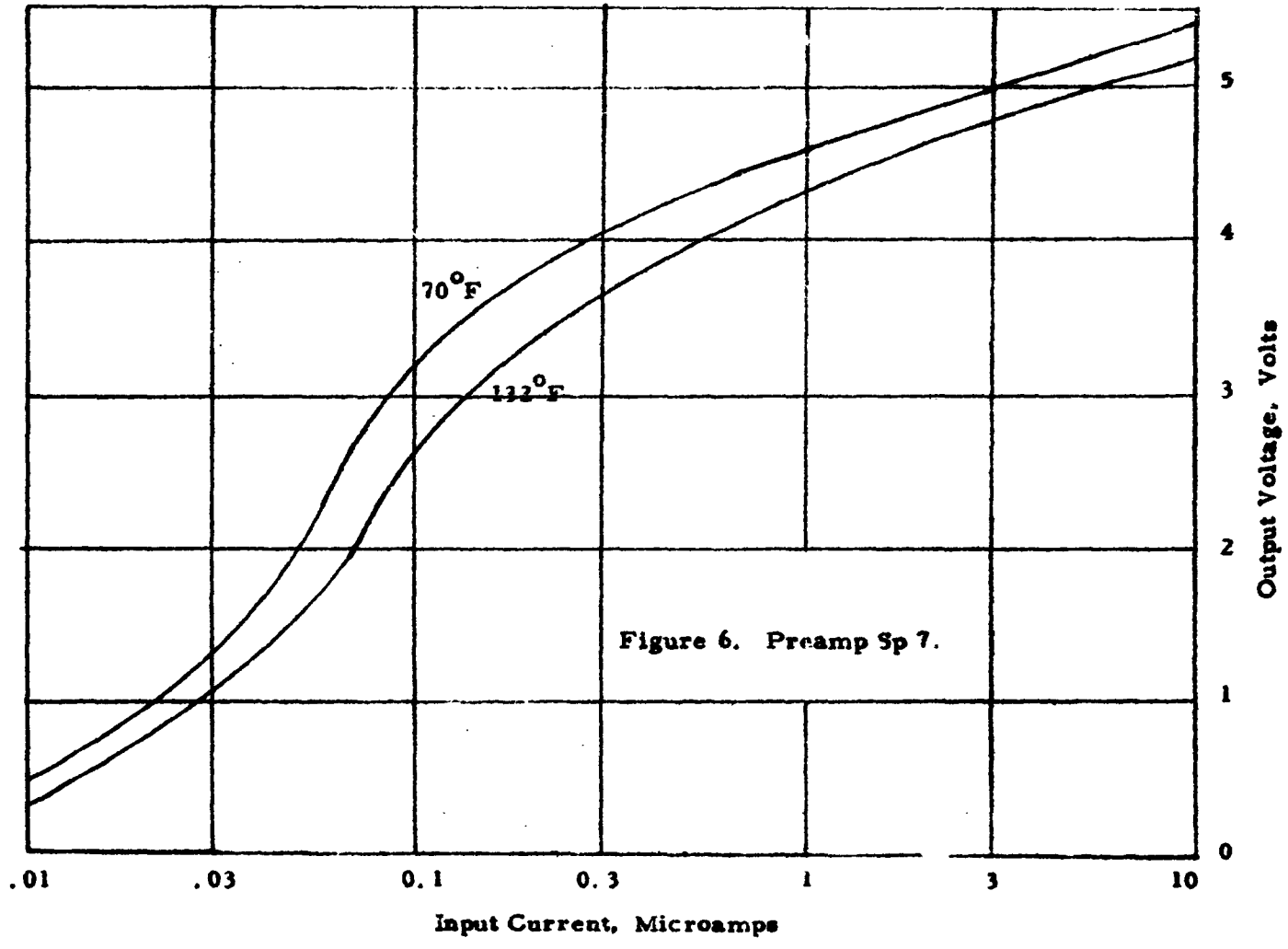

Figure 6. Preamp Sp 7.

Frequency Diversity Spectrometer

Texas Instruments Incorporated has designed and built a Frequency Diversity Spectrometer which shows promise for application to on-board instrumentation requirements.[2] It possesses the desirable features of a single detector and data transmission channel plus simultaneous measurement of a number of spectral wavelengths.

The incident radiation is dispersed by prisms or gratings, and the dispersed spectrum is then focused along the radius of a rotating chopping reticle. The chopper is designed so that a different chopping frequency occurs for each of the desired spectral increments. This is accomplished by making the number of segments on the chopper a function of its radius. Thus, the frequency of modulation corresponds to wavelength, and the amplitude corresponds to radiant intensity. After the reticle has frequency encoded the incident irradiance, the energy from all spectral increments is concentrated onto a single detector. A single amplifier is then used to drive the telemetry system. Analysis is made on narrow-band wave-analyzer equipment.

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[2] W. Beyen, "Proposal to Develop Prototype Spectrometer," Proposal No. A61-304, Texas Instruments Inc., Dallas, Texas; Oct.12, 1961.

Tentative specifications suggested for the Frequency Diversity Spectrometer are listed.

1) Wavelength range: 0.2 to 1.0 micron

2) Spectral resolution: 20 increments

3) Chopping frequencies: 1 to 2 kilocycles

4) Telemetry: IRIG FM-FM Channel 18

5) Field of view: 15 degrees

6) Entrance slit: 1 by 0.2 millimeters

7) Detector: multiplier phototube

8) Sensitivity: 2×10^{-9} watts per channel above 0.4 microns. Best effort toward 10^{-14} watts per channel below 0.4 microns.

9) Bandwidth: 20 cycles/second

10) Power input: 20 watts at 28 $\pm$ 10% volts dc

11) Weight: less than 20 pounds

12) Size: less than 300 cubic inches with no dimension greater than 17 inches

13) Altitude: to 200,000 feet

14) Acceleration: 10g linear on each axis
1/2 in. double amplitude, 2 to 20 cps
$\pm$ 8g, 20 to 2000 cps

PERSONNEL, ADMINISTRATIVE, AND FISCAL INFORMATION

PERSONNEL

The supervisory and technical personnel associated with the project are listed below. The research and development is conducted as Project EE-12 of the Electro-Dynamics Laboratory, Electrical Engineering Department, Engineering Experiment Station. The Laboratory is administered under Dr. Dean F. Peterson, Jr., Dean of the College of Engineering and Technology Dr. Vaughn E. Hansen, Director of the Engineering Experiment Station, and Dr. Clayton Clark, Chairman of the Engineering Research Committee at the Utah State University, all of whom serve without charge to the contract.

Utah State University Faculty Members

Prof. Larry S. Cole, Professor of Electrical Engineering and Head of Department, Project Director (1/5 time)

Dr. Doran J. Baker, Associate Professor of Electrical Engineering and Physics, Associate Project Director (9/10 time)

Prof. W. Arnold Finchum, Assistant Professor of Electrical Engineering (1/6 time)

Research Engineers

Mr. Clair L. Wyatt, Assistant Research Engineer, Assistant Project Director (Full time)

Mr. Duard S. Woffinden, Assistant Research Engineer, Instrumentation Supervisor (Full time)

Mr. Fon R. Brown, Assistant Research Engineer (4/5 time)
Mr. W. Keith Mortensen, Assistant Research Engineer (2/3 time)

Research Physicists

Mr. Louis C. Block, Assistant Research Physicist (Full time)
Mr. Roger H. Kleen, Assistant Research Physicist (Full time)
Mr. Ralph D. Briscoe, Assistant Research Physicist (1 Oct 61, 1/2 time)
Mr. Jay W. Phippen, Assistant Research Physicist (1 Oct 61, 1/2 time)

Research Technicians

Mr. Lloyd R. Taylor, Chief Technician (1/2 time after 1 Oct 61)
Mr. W. Lynn Bassett, Electronics Technician (1/2 time after 1 Oct 61)
Mr. D. Gail Larsen, Electronics Technician (1/2 time after 1 Oct 61)
Mr. William L. Brown, Electronics Technician (1/4 time)
Mr. Donn C. Goode, Draftsman (1/4 time
Mr. Craig A. Mortensen, Electronics Technician (1 Oct 61, 1/3 time)
Mr. A. Stanley Chipman, Electronics Technician (1/10 time)

Secretary

Mrs. Bonnie J. Allred, Stenographer-Typist (1 Oct 61, 1/2 time)

ADMINISTRATION AND TRAVEL

Administrative action consisted of directing the investigations of the spectral radiation characteristics of missile exhaust plumes and atmospheric shock waves, and the development of instrumentation for a series of rocketborne experiments. Mail and telephone communications were handled which concerned the technical planning and coordination of the various phases of the research effort.

Mr. L. C. Block travelled with AFCRL personnel to the facilities of ARPA, Washington, D.C., from 6 to 7 September 1961 to attend planning meetings. On 22 September 1961 C. L. Wyatt travelled to Texas Instruments, Inc., Dallas, Texas, and thence to Cape Canaveral AMR, Florida, to discuss the Frequency Diversity Spectrometer and to install the USU instrumentation for launch in Pod 3. Mr. L. R. Taylor travelled to the facilities of Cape Canaveral from 4 to 10 October 1961 for equipment installation.

FISCAL INFORMATION

The contract balance as of 1 October 1961 is approximately $193,945.87. This includes all expenditures and encumbrances, including overhead, from the total contractual authorization under AFCRL Contract No. AF19(604)-7423, Modification No. 2.

The following item of equipment was purchased:

1 ea., Power Supply, Power Sources Model PS4315M, Serial 148, USAF 19(604)-7423-USU 58, $795.00

ACKNOWLEDGEMENTS

The authors wish to thank Messrs. D.S. Woffinden, F.R. Brown, and L.R. Taylor for their contributions to the substance and preparation of this report. The guidance of Messrs. H.P. Gauvin, J.J. Lovett, J.E. Grenier, and Dr. A.T. Stair, Jr., of the AFCRL Thermal Radiation Laboratory is appreciated. Recognition is extended to President Daryl Chase, Vice President M.R. Merrill, Dr. D.F. Peterson, Jr., Dr. V.E. Hansen, and Dr. C. Clark of USU for their enthusiastic support of the research effort.

The cooperation and assistance of the Astronautics personnel under Mr. C.L. Bates is gratefully recognized.